national accelerator laboratory EXP-69
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ACCELERATOR EXPERIMENT: Tune vs Radius and vs Time in the Booster

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Both vertical and horizontal tunes have been measured vs time and radius in the Booster. This was running in the ordinary acceleration mode with a single ORBUMP turn injected, debuncher on and about 40 mA of beam accelerated at 8 GeV.

The radius was changed with an RF bump. The vertical tune was measured by kicking the beam with the notcher, and the horizontal tune by kicking the beam with the injection kicker.

First, the tunes were measured at different instants of a "typical" acceleration cycle. The results are shown in Figs. 1 and 2. The radial position of the beam is also shown in Fig. 1. As one can see, the acceleration cycle was not that "typical" because during the early part, the beam has been running too much to the inside. But from 3 ms on the beam followed the regular pattern. The measured values are shown in the tune diagram in Fig. 2. If one disregards the anomalous part up to 3 ms, the "working curve" is all confined inside the triangle ABC. This happened to be a rather good choice. It is desirable to squeeze the "working curve" even more inside the triangle ABC, for instance with a programmed RF bump and sextupoles and/or trim quads. Or, alternatively, one should have some sort of control of the three resonances:

$$2\nu_y - \nu_x = 7, \quad 3\nu_x = 20 \text{ and } \nu_x + 3\nu_y = 27.$$

Finally, the tunes have been measured versus radius at 5 ms, 16 ms and 28 ms. The fractional part of the vertical tune is shown versus radius in the Figs. 3, 4, and 5. The fractional part of the horizontal tune is shown in the Figs. 6, 7, and 8. The radius difference x corresponds to L18 and L20. The calibration between the unit u of the horizontal scale and the actual difference x has been worked out by R. Peters.

$$x_{mm} = 0.87947 \cdot u_{mm} + 1.4578 .$$

There is still some uncertainty about the location of the centre x = 0.

The vertical tune versus radius behaves as expected: a smooth, linear change with the beam momentum across the entire aperture. In particular, the vertical chromaticity is practically cancelled around the transition energy to cure the head-tail effect.

Also the horizontal tune has a smooth behavior at 5 ms, with a change of about 0.1 across the aperture. Nevertheless, at high energy, as one can see from the Figs. 7 and 8, the tune has a strange pattern. It is practically constant for radii larger than u = - 3 mm, and increases steeply below this value. We cannot offer, so far, any explanation of this fact. Noticeable beam losses were observed, after kicking, in the middle of the flat region as well as in the middle of the raising part. The third order resonances was also observed at 16 ms. It seemed there was some correlation with the amplitude of the coherent oscillations, as one can see also in Fig. 9 where horizontal tune is plotted versus kicker voltage. Clearly the beam with large oscillation amplitude is locked to the third order resonance.

In order to confirm the tune versus radius measurement results, we detected the coherent oscillations versus number of revolutions for two different radius at the same time of 28 ms and with the same kicker voltage. They are shown in Figs. 10 and 12. Figs. 11 and 13 show the Fourier analysis of the signals. Because of the momentum spread in the beam, there is also a tune spread which depends on the local slope of the tune versus radius. When the beam is at u = - 8 mm there is a large variation of tune across the beam and the coherent oscillations decay fast. This is confirmed by

Figs. 10 and 11. On the contrary, at u = 4 mm there is practically no tune variation and the coherent oscillations stay for a much longer time, as one can see from Figs. 12 and 13.

A.G. Ruggiero

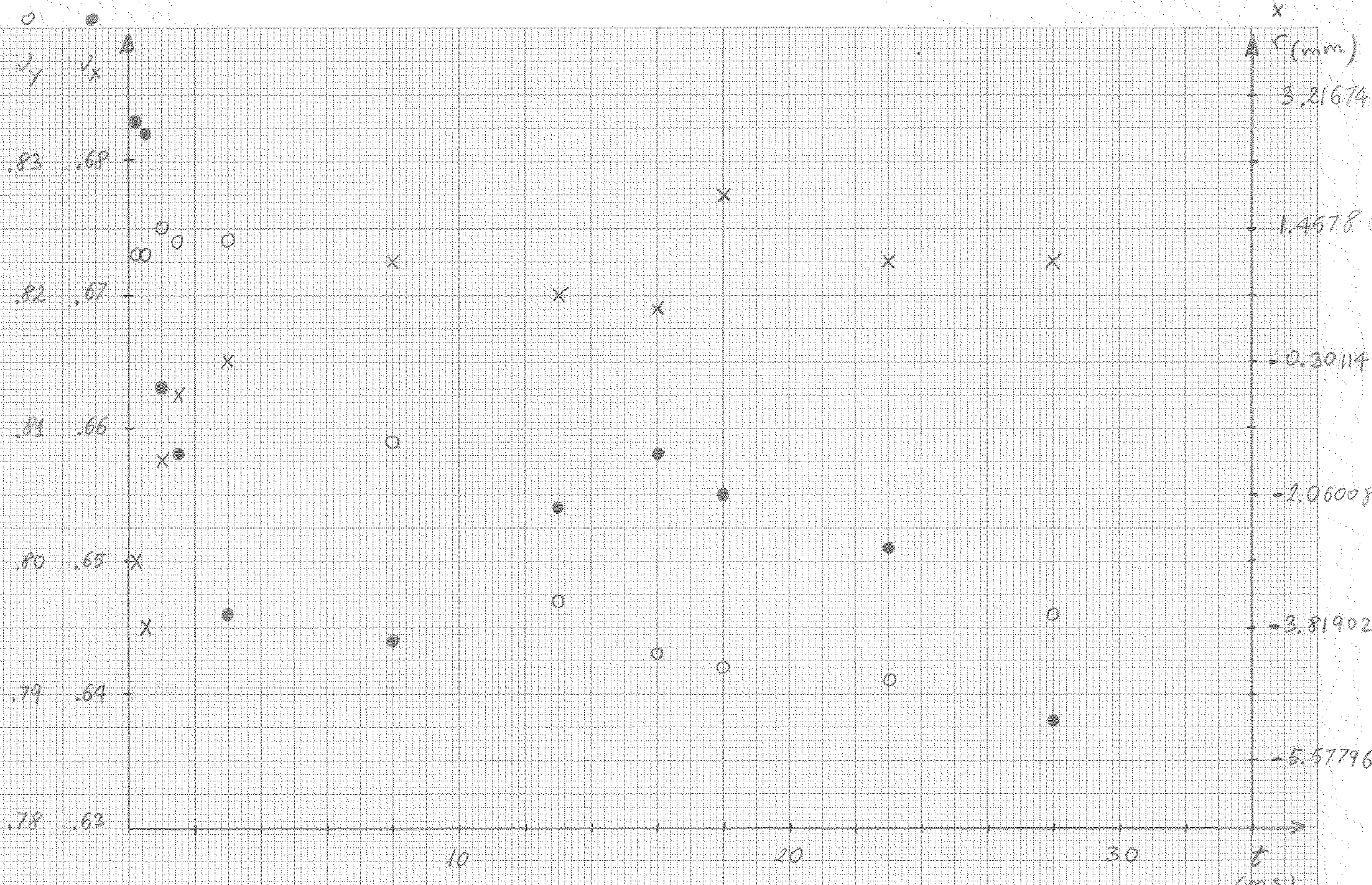

ν_y ν_x
.83 .68
.82 .67
.81 .66
.80 .65
.79 .64
.78 .63
r (mm)
3.21674
1.4578
0.30114
-2.06008
-3.81902
-5.57796
10
20
30
t (ms)

FIG. 1

1 -	0.2 ms	7 -	13 ms
2 -	0.5	8 -	16
3 -	1.0	9 -	18
4 -	1.5	10 -	23
5 -	3.0	11 -	28
6 -	8.0		

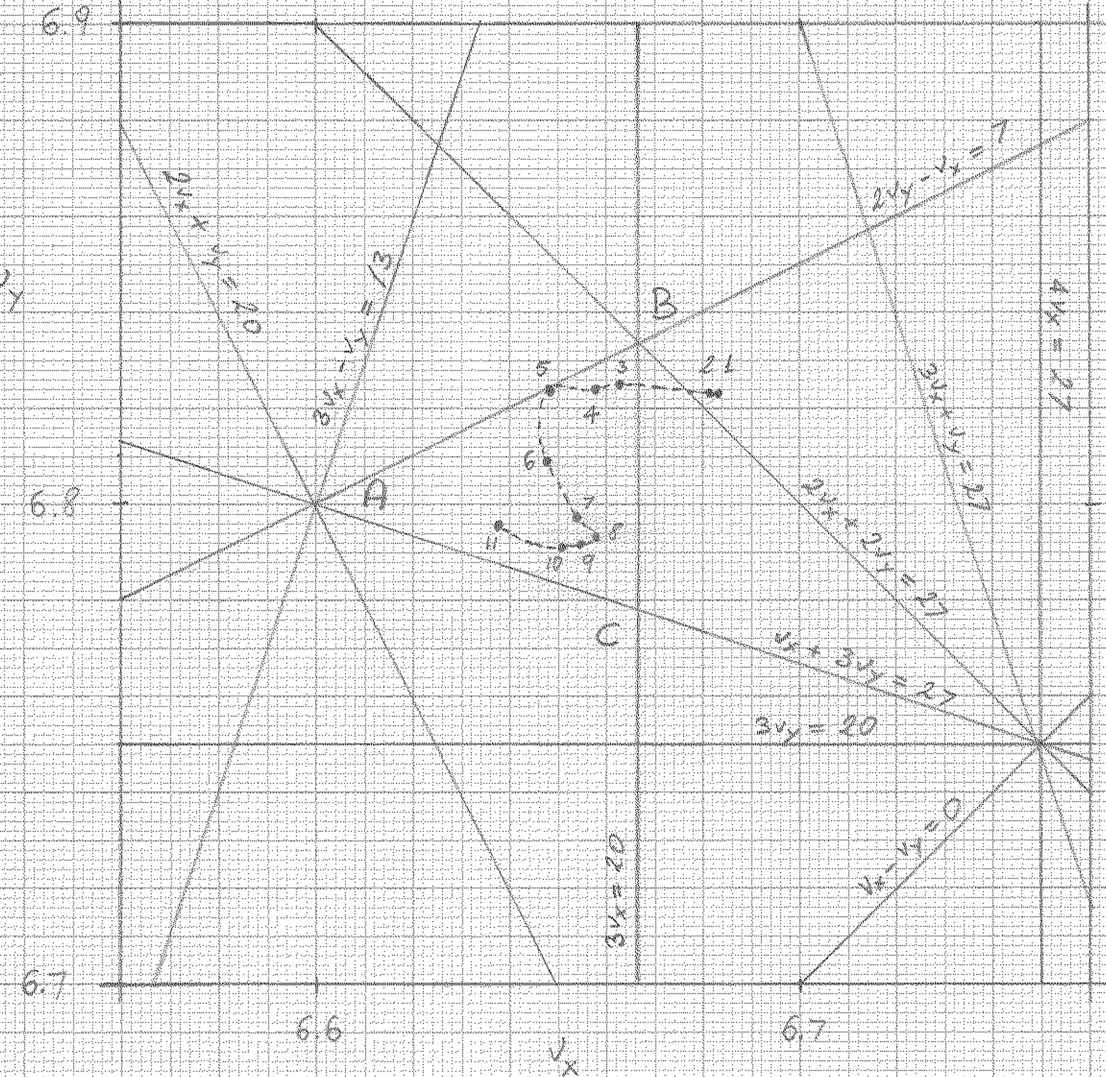


FIG. 2

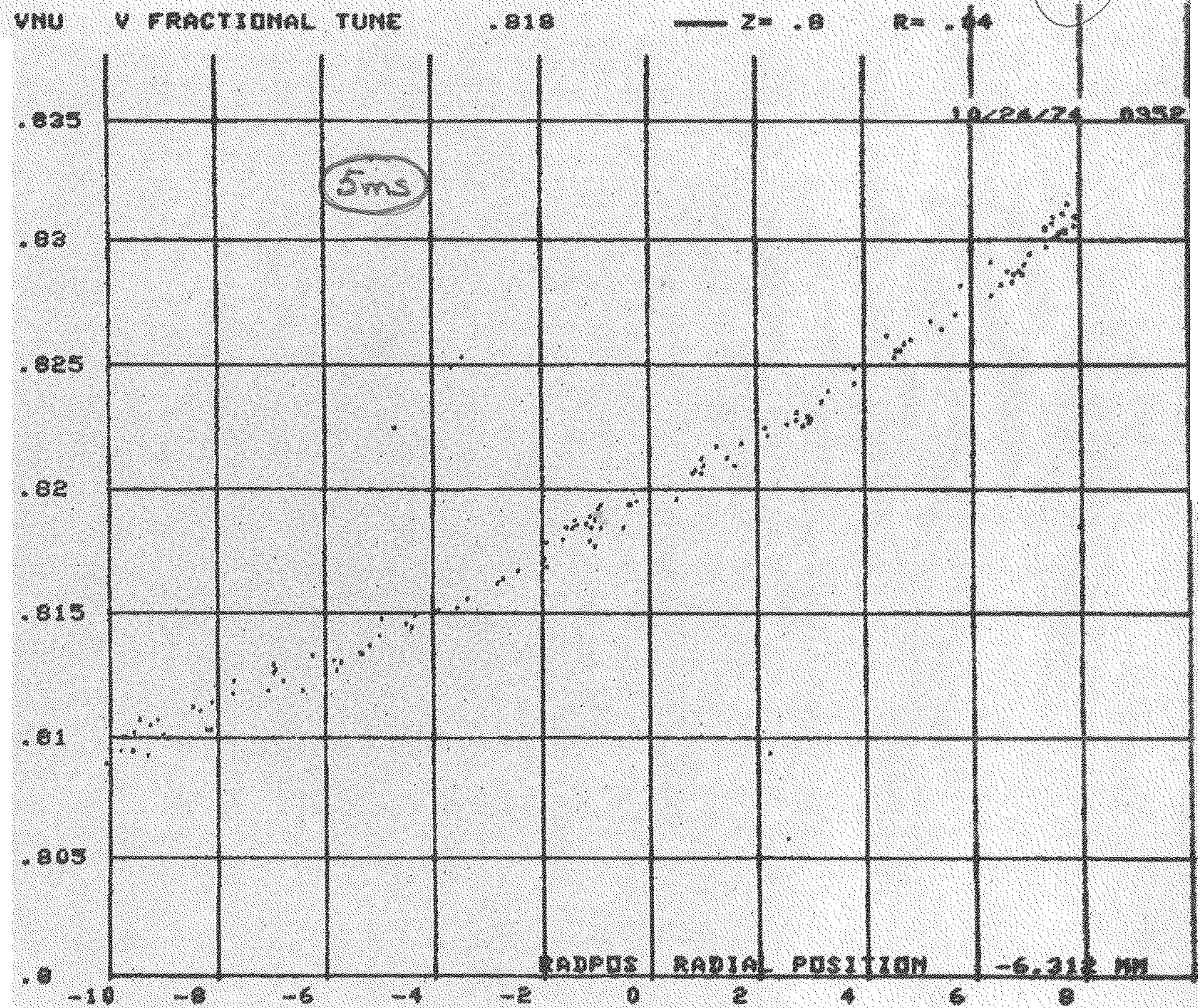

VNU V FRACTIONAL TUNE .818
Z= .8 R= .44
10/24/74 0952
5ms
.835
.83
.825
.82
.815
.81
.805
.8
-10
-8
-6
-4
-2
0
2
4
6
8
RADPOS RADIAL POSITION -6.312 MM

Fig. 3

18000

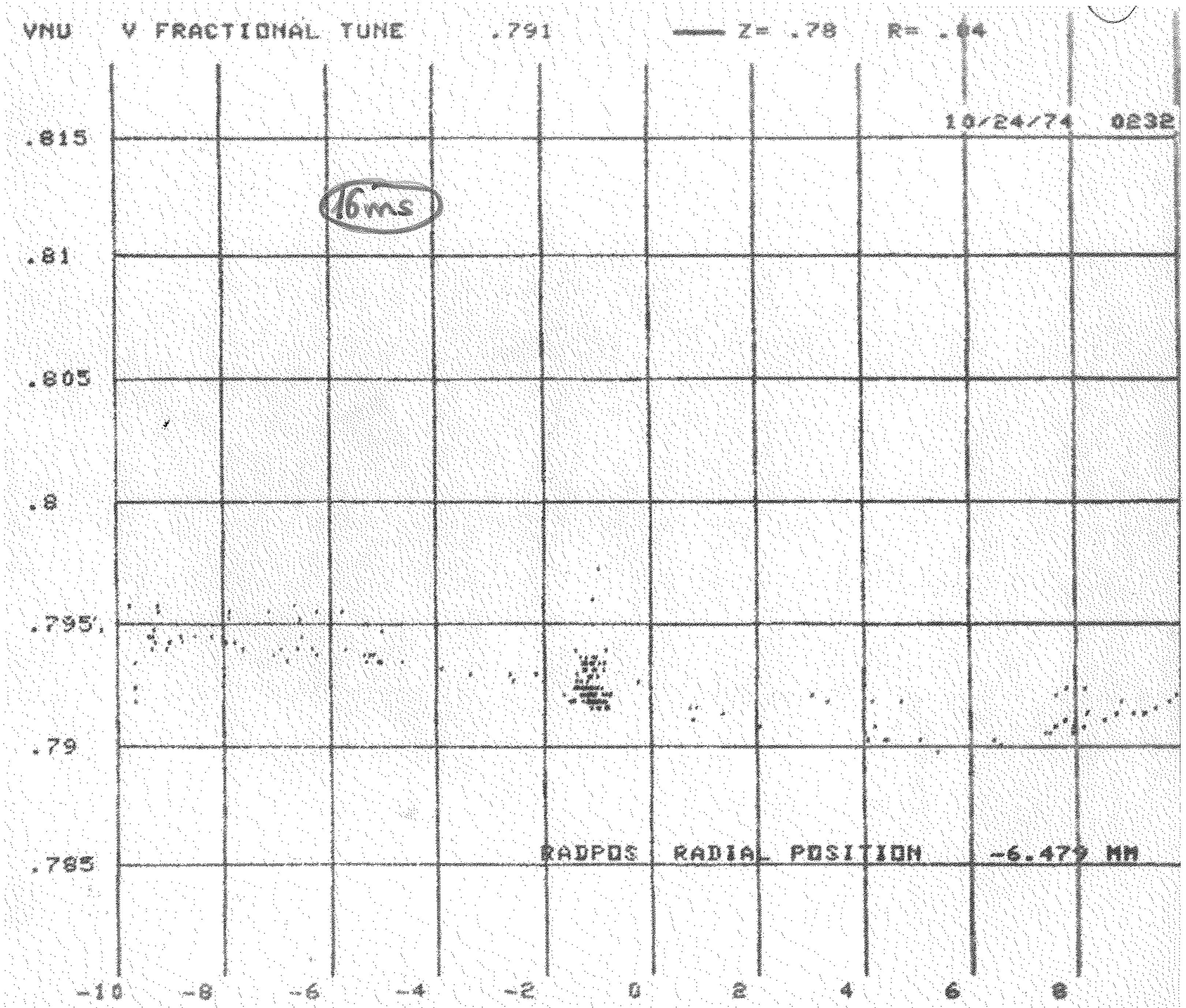
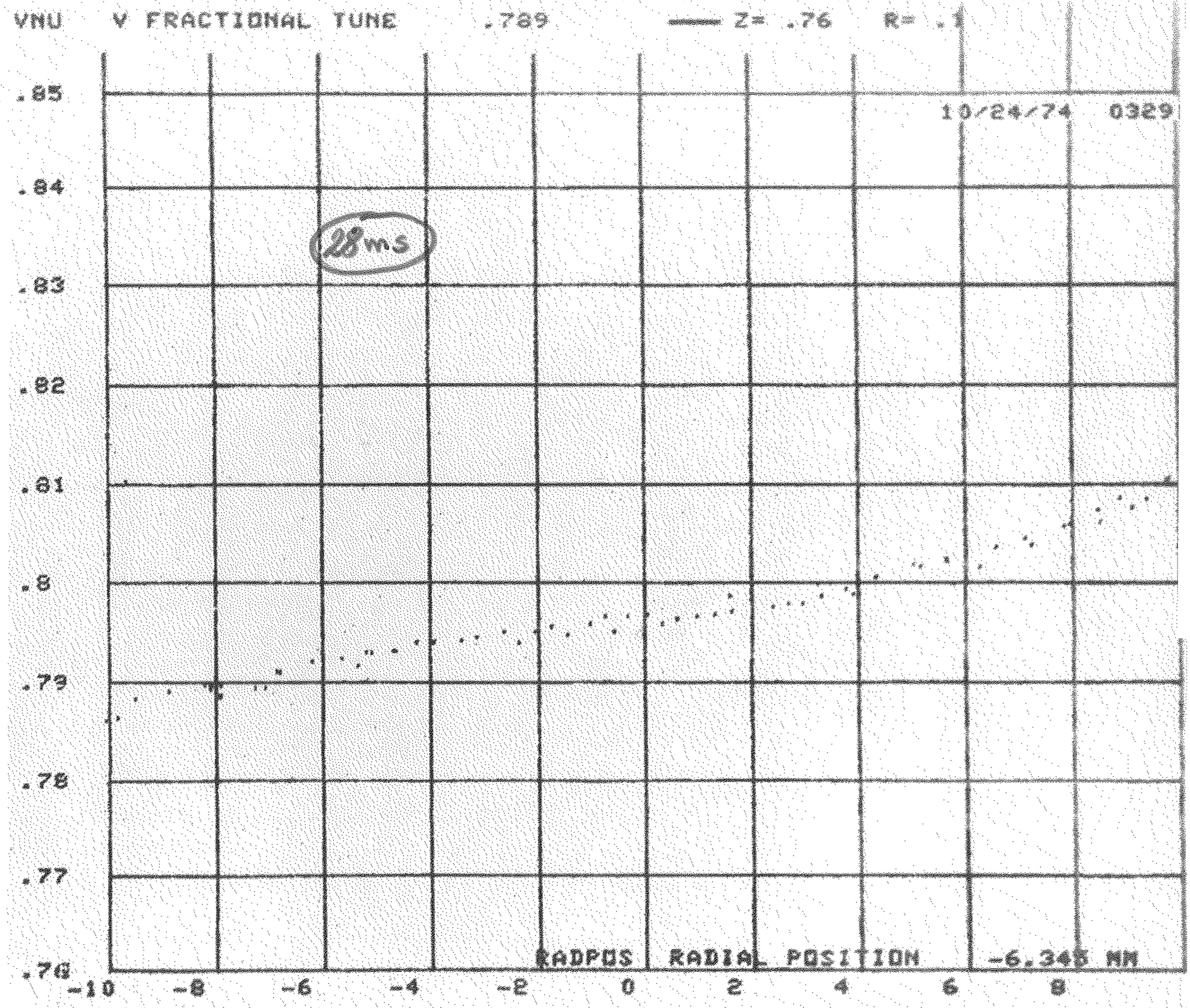

VNU V FRACTIONAL TUNE .791
Z= .78 R= .04
10/24/74 0232
16ms
.815
.81
.805
.8
.795
.79
.785
RADPOS RADIAL POSITION -6.479 MM
-10 -8 -6 -4 -2 0 2 4 6 8

Fig. 4

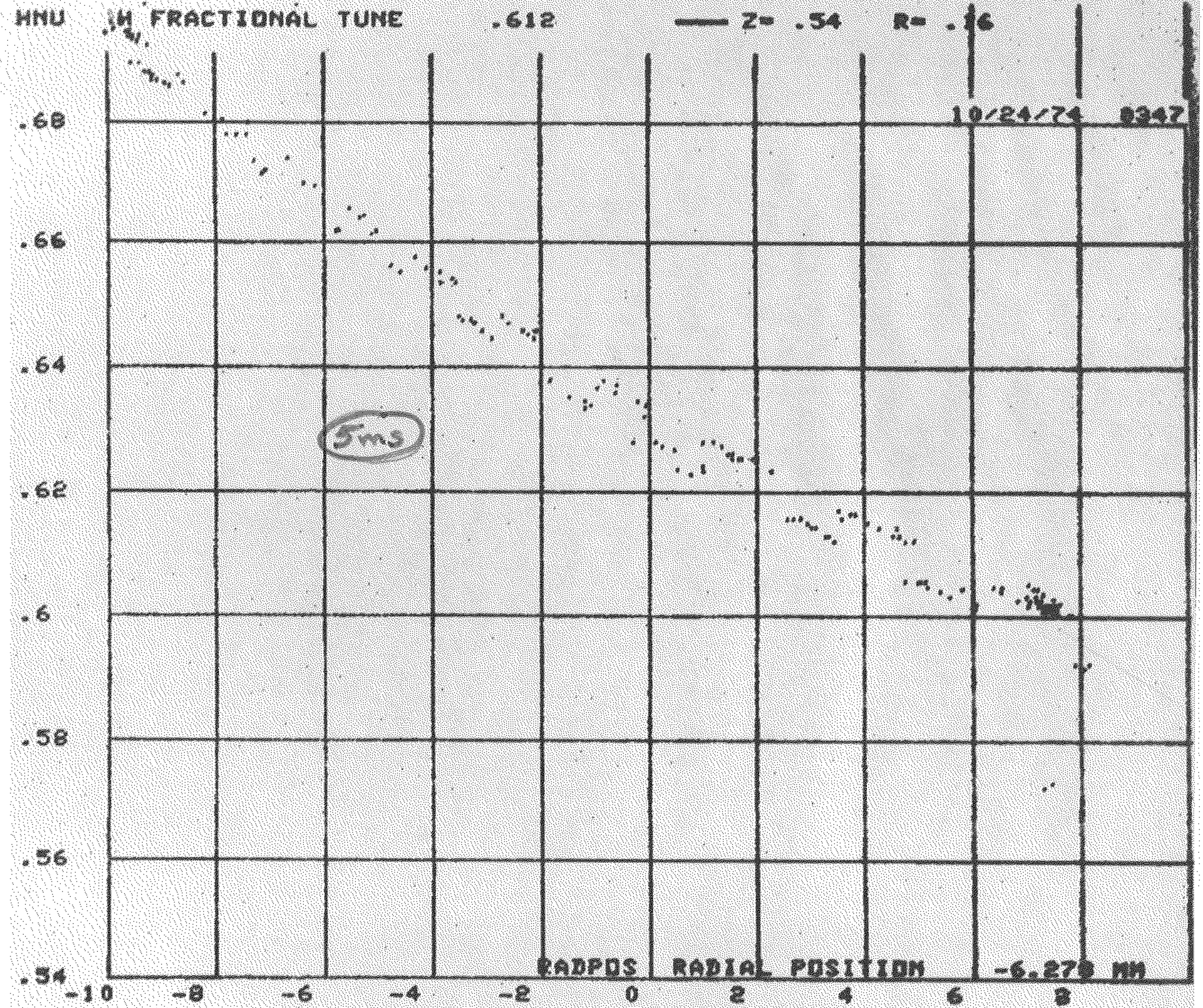
30 K



VNU V FRACTIONAL TUNE .789 Z= .76 R= .1
10/24/74 0329
28 ms
.85
.84
.83
.82
.81
.8
.79
.78
.77
.76
-10
-8
-6
-4
-2
0
2
4
6
8
RADPOS RADIAL POSITION -6.345 MM

FIG. 5

7K



HNU H FRACTIONAL TUNE .612
Z= .54 R= .16
10/24/74 0347
.68
.66
.64
.62
.6
.58
.56
.54
-10
-8
-6
-4
-2
0
2
4
6
8
5ms
RADPOS RADIAL POSITION -6.278 MM

FIG. 6

3.089 KV

18K

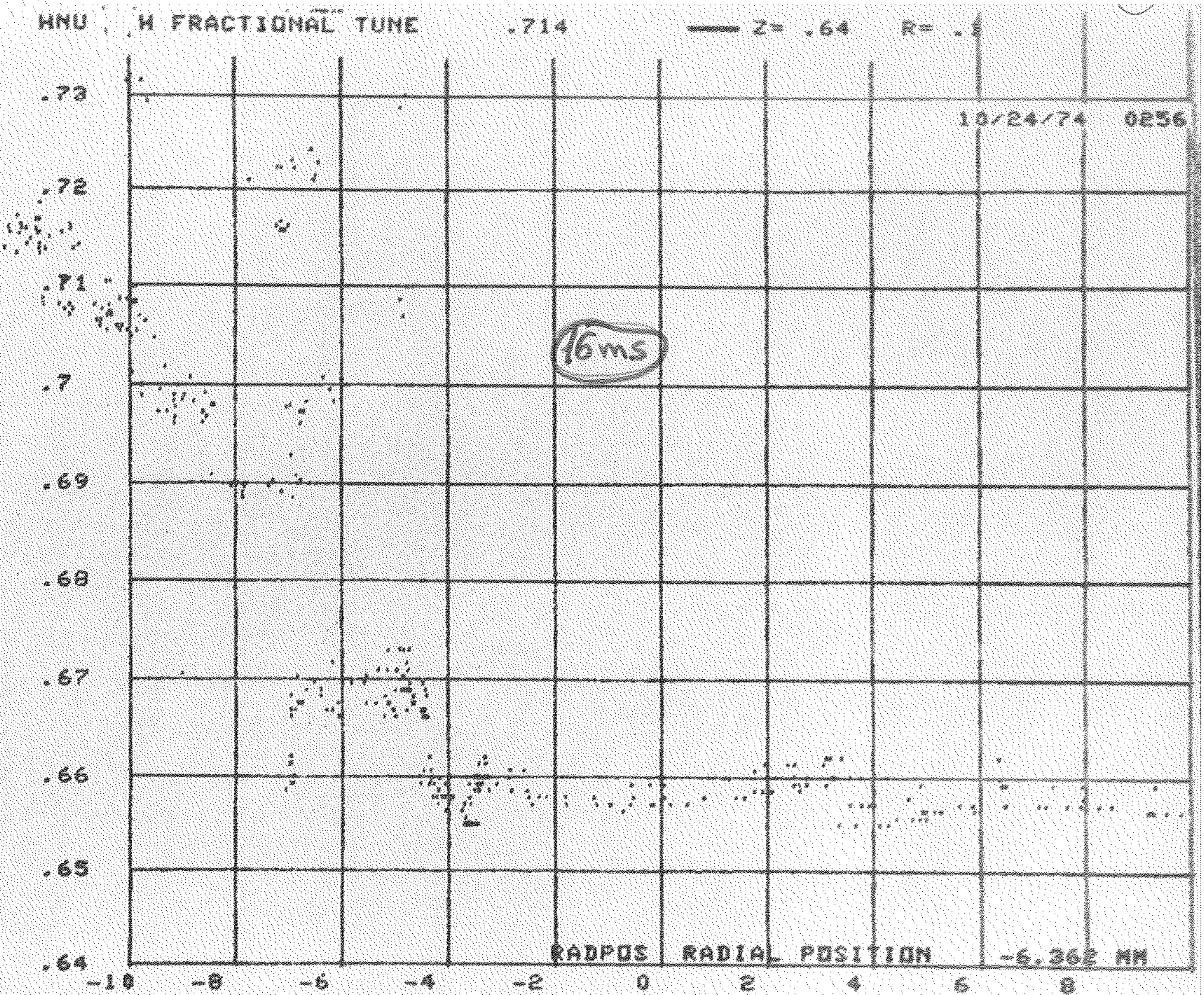


FIG. 7

5.4 KV

30K

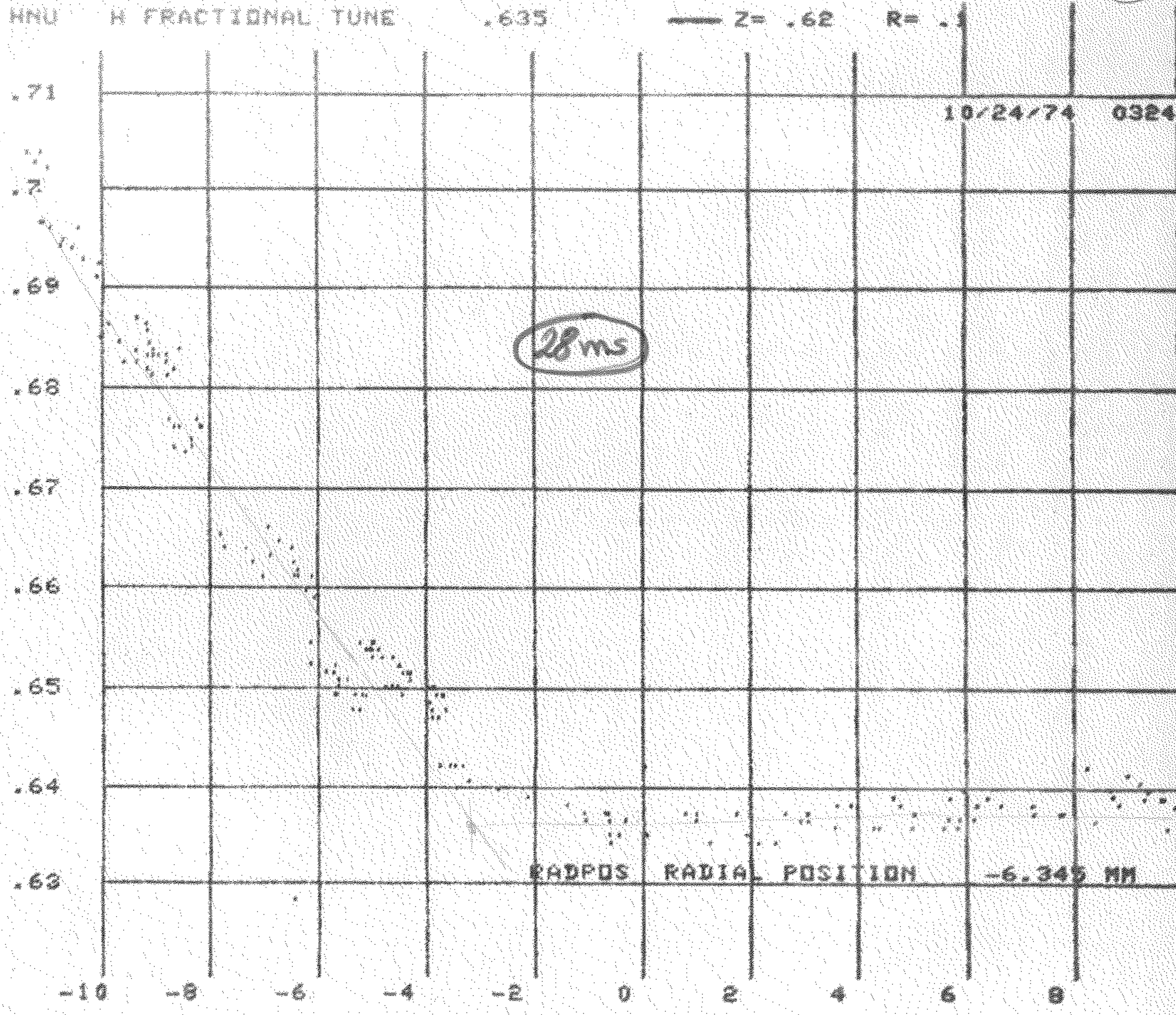
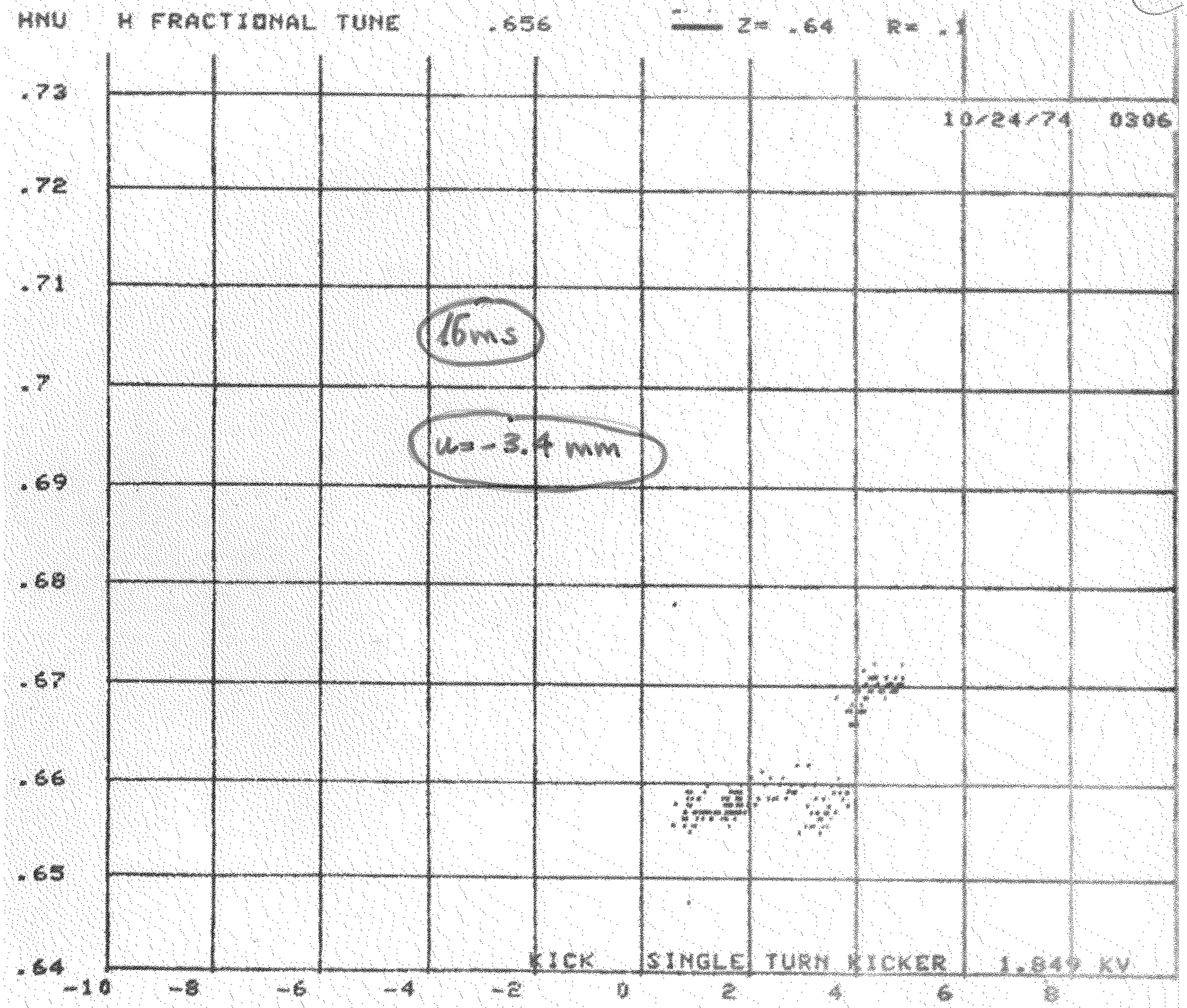


FIG. 8

$R = 7.4$



HNU H FRACTIONAL TUNE .656
Z= .64 R= .1
10/24/74 0306
.73
.72
.71
.7
.69
.68
.67
.66
.65
.64
-10
-8
-6
-4
-2
0
2
4
6
8
16ms
u= -3.4 mm
KICK SINGLE TURN KICKER 1.849 KV

FIG. 9

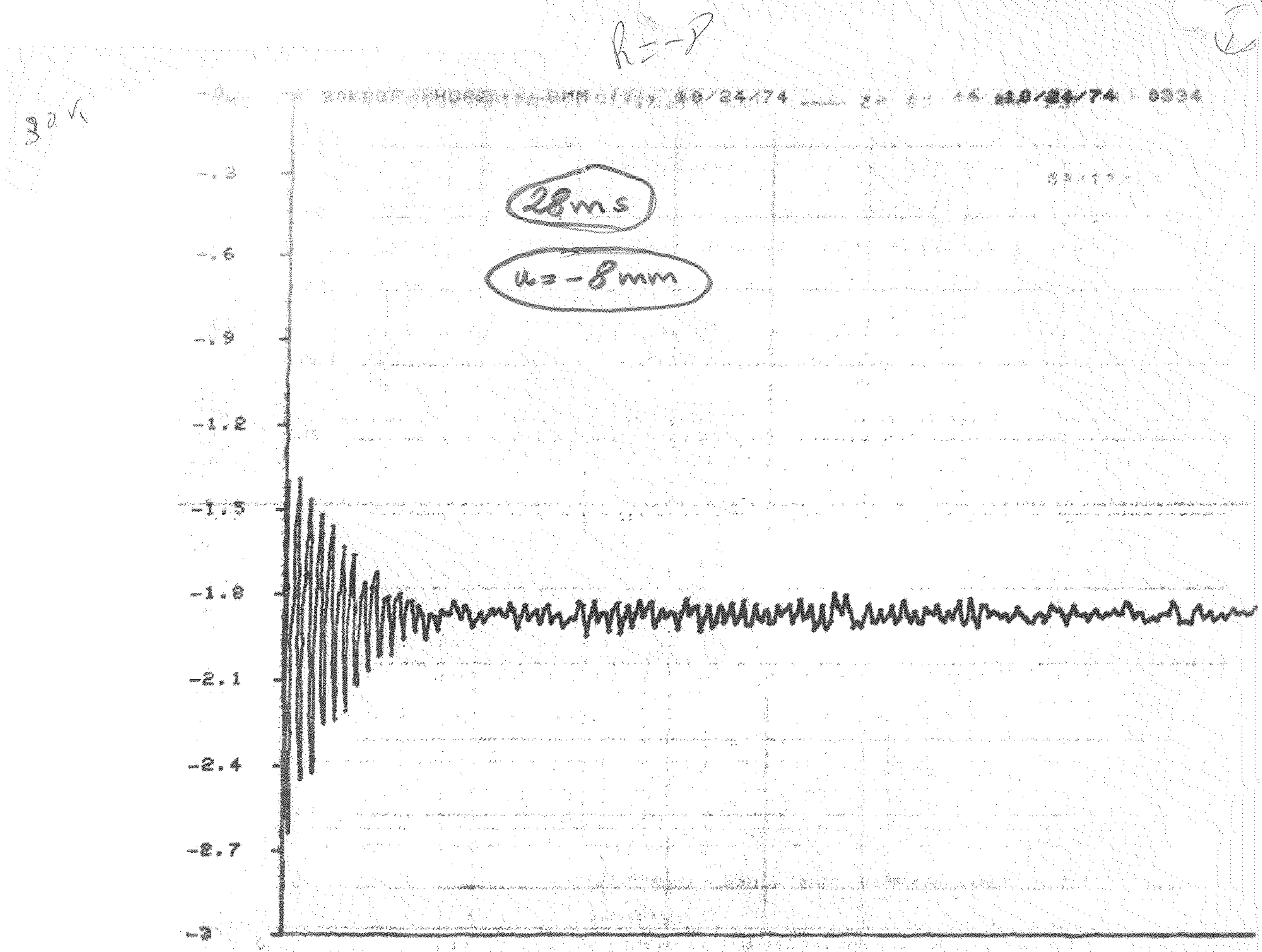


FIG. 10

80K

R=-8

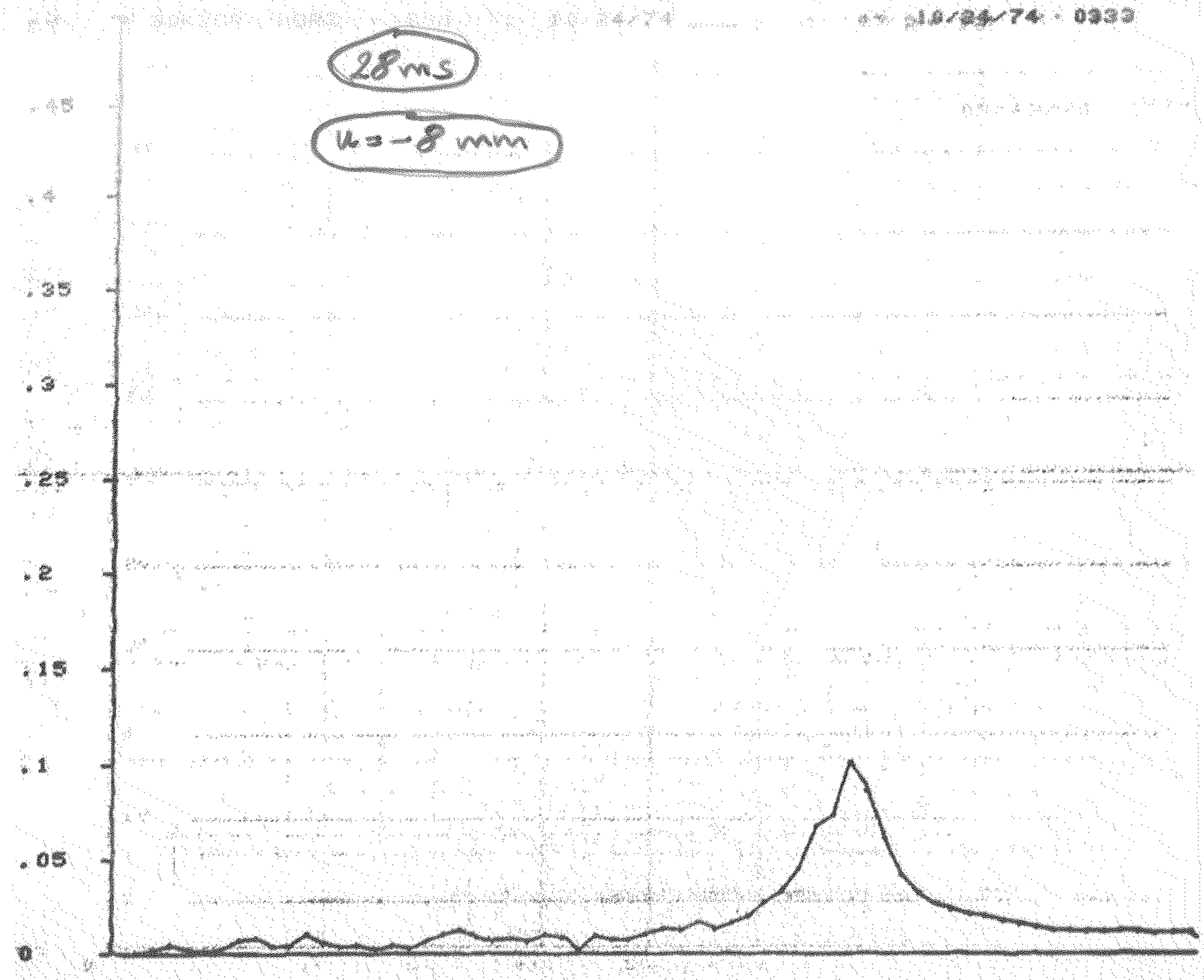


Fig. 11

128 Pts

30K

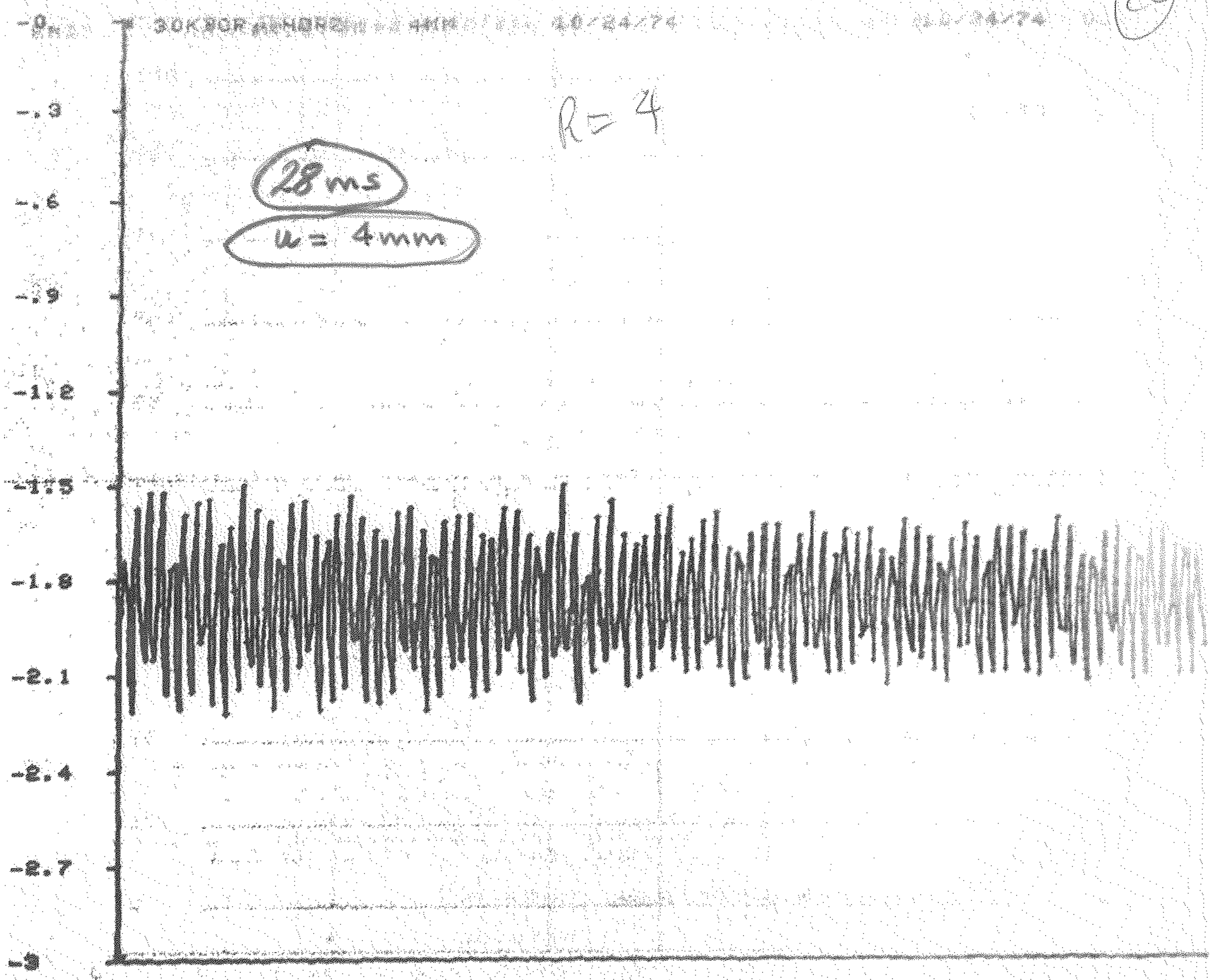


FIG. 12